EMBEDDING DATA IN MATERIAL

Background of the Invention

FIELD OF THE INVENTION

The present invention relates to embedding data in material. Embodiments of the present invention relate to watermarking.

Material as used herein means information material represented by information signals and material includes at least one or more of image material, audio material and data material. Image material is generic to still and moving images and includes video and other forms of information signals represents images.

Description of the Prior Art

Steganography is the embedding of data into material such as video material, audio material and data material in such a way that the data is imperceptible in the material.

Data may be embedded as a watermark in material such as video material, audio material and data material. A watermark may be imperceptible or perceptible in the material.

A watermark may be used for various purposes. It is known to use watermarks for the purpose of protecting the material against, or trace, infringement of the intellectual property rights of the owner(s) of the material. For example a watermark may identify the owner of the material.

Watermarks may be "robust" in that they are difficult to remove from the material. Robust watermarks are useful to trace the provenance of material which is processed in some way either in an attempt to remove the mark or to effect legitimate processing such as video editing or compression for storage and/or transmission. Watermarks may be "fragile" in that they are easily damaged by processing which is useful to detect attempts to remove the mark or process the material.

Visible watermarks are useful to allow e.g. a customer to view an image e.g. over the Internet to determine whether they wish to buy it but without allowing the customer access to the unmarked image they would buy. The watermark degrades the image and the mark is preferably not removable by the customer. Visible watermarks

are also used to determine the provenance of the material into which they are embedded.

Figure 1 shows one such known apparatus, generally 100, for embedding a transform domain watermark in an image. The image 105 is received by the transformer 110 and output as a transform domain image 115. The transform domain watermark 145 is then applied to the transform domain image 115 by the combiner 120 which outputs a transform domain watermarked image 125. The transform domain watermarked image 125 is then received by the inverse transformer 130 and output as a spatial domain watermarked image 135.

However, a problem arises in that the image 105 may be degraded by the operation of both the transformer 110 and inverse transformer 130. The transformers 110, 130 need to be very accurate to ensure that any degradation is minimised. Accurate transformers are relatively expensive and two are required.

SUMMARY OF THE INVENTION

According to one aspect of the present invention there is provided an apparatus comprising a transformer for transforming transform domain data into spatial domain data; and a combiner for receiving material and combining said spatial domain data with said material to form data embedded material.

Hence, in preferred embodiments the material is not subject any transformation at all. One less transformer is required than the prior art approach thereby reducing cost and complexity. Advantageously, since only the transform domain watermark is transformed the transformer can have less precision and range thereby further reducing cost and complexity.

According to another aspect of the present invention there is provided a method comprising the steps of a) transforming transform domain data into spatial domain data; and b) combining said spatial domain data with material to form data embedded material.

According to a further aspect of the present invention there is provided a computer program product arranged to carry out the method of said another aspect when run on a computer.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages of the invention will be apparent from the following detailed description of illustrative embodiments which is to be read in connection with the accompanying drawings, in which:

Figure 1 is a block diagram illustrating a prior art watermarking apparatus;

Figure 2 is a block diagram illustrating a watermark apparatus according to an embodiment of the present invention;

Figure 3 is a block diagram illustrating a watermark apparatus according to another embodiment of the present invention;

Figure 4 is a block diagram illustrating an embodiment of the strength adapter of Figure 3;

Figure 5 is a block diagram illustrating a watermark apparatus according to a further embodiment of the present invention;

Figures 6A and 6B illustrate a UMID structure; and

Figures 7A and 7B illustrate wavelet processing and notation.

DESCRIPTION OF PREFERRED EMBODIMENTS

Whilst the embodiments described herein refer to images and watermarking images it will be appreciated that the technique can be equally be applied to other material such as audio, video and data generally.

Figure 2 illustrates a watermark apparatus, generally 200, according to an embodiment of the present invention. The watermark apparatus 200 comprises an inverse transformer 210 and a combiner 220. In overview, the watermark apparatus 200 receives a spatial domain image 105 and a transform domain watermark 145, and outputs a spatial domain watermarked image 225. The transform domain watermark 145 is inverse transformed in a transformer 210 and combined with the spatial domain image 105 in a combiner 220 to produce the spatial domain watermarked image 225. Only the transform domain watermark 145, and not the spatial domain image 105, is subject to subject any transformation. The spatial domain image 105 is not subject to any lossy processing which may degrade the spatial domain image 105 and is fully recoverable.

Spatial Domain Image 105

The spatial domain image 105 is preferably a digital bitmap. The digital bitmap comprises of a plurality of pixels, each pixel having a particular binary value.

Transform Domain Watermark 145

The transform domain watermark 145 comprises encoded watermark information. The transform domain watermark 145 is preferably a digital bitmap. The digital bitmap comprises of a plurality of pixels, each pixel having a particular binary value, each particular binary value encoding the watermark information.

The transform domain watermark 145 may comprise wavelet coefficients, each coefficient being represented by one pixel of the digital bitmap. Wavelets are described in more detail below the section entitled wavelets. The value of each wavelet coefficient encodes the watermark information. The wavelet has watermark information which is encoded in coefficients in at least two bands in at least one level. In preferred embodiments, the upper horizontal band, hH_1, hV_1 and the upper vertical band, lH_1, hV_1 are used to encode the watermark information as watermark information encoded in these bands have been found not to be readily perceptible in the spatial representation. Furthermore, watermark information is encoded in these bands because it has been found to be robust to image compression techniques such as those agreed by the Joint Picture Expert Group (JPEG). However, it will be appreciated that the watermark information may be encoded in any suitable coefficients and any band or level as appropriate.

Alternatively, the transform domain watermark 145 may comprise Discrete Cosine Transform (DCT) coefficients, each coefficient being represented by one pixel of the digital bitmap. DCTs are well known in the art. Preferably, the value of each DCT coefficient encodes the watermark information.

The watermark information may, for example, identify the owner of the spatial domain image 105 or provide other information associated with the spatial domain image 105. Preferably, the watermark information comprises a Universal Material Identifier (UMID) associated with the spatial domain image 105. The use of a UMID is advantageous as it provides for unique identification of the spatial domain image

105. UMIDs are described in more detail below in the section entitled UMIDs. Preferably, the watermark information is encoded by a Pseudo Random Symbol Stream. The use of Pseudo Random Symbol Stream encoding is advantageous as it reduces the visual perceptibility of the watermark and makes it more difficult for the watermark information to be isolated or removed. The Pseudo Random Symbol Stream spreads the watermark over many coefficients. Encoding or 'spreading' using Pseudo Random Symbol Stream's is well known in the art. The watermark information may also be subject to error correction coding to improve decoding success rates.

Inverse Transformer 210

The inverse transformer 210 receives the transform domain watermark 145 and transforms transform domain watermark 145 into a spatial domain watermark 215. Where the transform domain watermark 145 comprises wavelet coefficients, the inverse transformer 210 comprises an inverse wavelet transformer. Where the transform domain watermark 145 comprises DCT coefficients, the inverse transformer 210 comprises an inverse DCT transformer. It will be appreciated that other techniques for transform domain representation may also be used and suitable inverse transformers will be required as appropriate. Since only the transform domain watermark 145, and not the spatial domain image 105, is to be transformed the inverse transformer 210 can have less precision and range thereby further reducing cost and complexity. Any losses introduced into the spatial domain watermark 215 by the inverse transformer 210 may be recovered using decoding techniques such as error correction coding.

The spatial domain watermark 215 is preferably a digital bitmap. The digital bitmap comprises of a plurality of pixels, each pixel having a particular value.

Combiner 220

The combiner 220 receives the spatial domain image 105 and the spatial domain watermark 215, and outputs a spatial domain watermarked image 225. The combiner 220 arithmetically combines respective pixels of the spatial domain image 105 and the spatial domain watermark 215 to produce the spatial domain watermarked image 225.

Alternative Embodiment

Figure 3 illustrates a watermark apparatus, generally 300, according to another embodiment of the present invention. The watermark apparatus 300 is similar to the arrangement of Figure 2 but with the inclusion of a strength adapter 310. The strength adapter 310 adapts the strength of the spatial domain watermark 215 in dependence on the spatial domain image 105 to produce a strength adapted spatial domain watermark 315. The combiner 220 arithmetically combines respective values of the spatial domain image 105 and the strength adapted spatial domain watermark 315 to produce a spatial domain watermarked image 325.

The strength adapter 310 allows the strength of the watermark spatial domain watermark 215 to be adapted such that the strength adapted spatial domain watermark 315 is not readily perceptible in the spatial domain watermarked image 325. Each pixel of the spatial domain watermark 215 may be individually adapted in dependence on respective pixels of the spatial domain image 105. Alternatively, a predetermined number of pixels of the spatial domain watermark 215 may be adapted in dependence on particular representative pixels of the spatial domain image 105.

Figure 4 illustrates an embodiment of the strength adapter of Figure 3. The strength adapter 310 comprises a generator 410 and a multiplier 420. The generator 410 receives the spatial domain image 105 and generates strength control information 415. The strength control information 415 is received by the multiplier 420 which, in response, adapts the magnitude of the spatial domain watermark 215 to produce a strength adapted spatial domain watermark 315.

The generator 410 may generate strength control information 415 such that each pixel of the spatial domain watermark 215 may be individually adapted in dependence on respective pixels of the spatial domain image 105. Alternatively, the generator 410 may generate strength control information 415 such that a predetermined number of pixels of the spatial domain watermark 215 may be adapted in dependence on particular representative pixels of the image 105. The strength control information 415 (α) is generated using the algorithm $\alpha = F(\text{Image})$, where $F(\text{Image})$ is a function representing the ability of the image 105 to mask respective pixels of the spatial domain watermark 215.

The strength adapted spatial domain watermark 315 is then combined by the combiner 220 with the image 105 to produce a spatial domain watermarked image 325 as described above.

Further Embodiment

Figure 5 illustrates a watermark apparatus, generally 400, according to a further embodiment of the present invention. The watermark apparatus 400 is similar to the arrangement of Figure 4 but with the strength adaptation being performed in the transform domain instead of the spatial domain. Hence, a transformer 430 is provided which transforms the spatial domain image 105 into a transform domain image 535.

The generator 410 receives the transform domain image 535 and generates strength control information 515. The strength control information 515 is received by the multiplier 420 which, in response, adapts the magnitude of the transform domain watermark 145 to produce a strength adapted transform domain watermark 545.

The generator 410 may generate strength control information 515 such that each pixel of the transform domain watermark 145 may be individually adapted in dependence on respective pixels of the transform domain image 535. Alternatively, the generator 410 may generate strength control information 515 such that a predetermined number of pixels of the transform domain watermark 145 may be adapted in dependence on particular representative pixels of the transform domain image 535.

The inverse transformer 210 receives the strength adapted transform domain watermark 545 and transforms the strength adapted transform domain watermark 545 into a strength adapted spatial domain watermark 555.

The strength adapted spatial domain watermark 555 is then combined by the combiner 220 with the spatial domain image 105 to produce a spatial domain watermarked image 525 as described above.

Hence, it will be appreciated that only the transform domain watermark 145, and not the image 105, is subject to subject any transformation. Accordingly, the image 105 is not subject to any lossy processing and will be fully recoverable.

UMIDs

Figures 6A and 6B illustrate a UMID structure.

The UMID is described in SMPTE Journal March 2000. Referring to Figure 6A an extended UMID is shown. It comprises a first set of 32 bytes of basic UMID and a second set of 32 bytes of signature metadata.

The first set of 32 bytes is the basic UMID. The components are:

•A 12-byte Universal Label to identify this as a SMPTE UMID. It defines the type of material which the UMID identifies and also defines the methods by which the globally unique Material and locally unique Instance numbers are created.

•A 1-byte length value to define the length of the remaining part of the UMID.

•A 3-byte Instance number which is used to distinguish between different 'instances' of material with the same Material number.

•A 16-byte Material number which is used to identify each clip. Each Material number is the same for related instances of the same material.

The second set of 32 bytes of the signature metadata as a set of packed metadata items used to create an extended UMID. The extended UMID comprises the basic UMID followed immediately by signature metadata which comprises:

•An 8-byte time/date code identifying the time and date of the Content Unit creation.

•A 12-byte value which defines the spatial co-ordinates at the time of Content Unit creation.

•3 groups of 4-byte codes which register the country, organisation and user codes

Each component of the basic and extended UMIDs will now be defined in turn.

The 12-byte Universal Label

The first 12 bytes of the UMID provide identification of the UMID by the registered string value defined in Table 1.

Byte No.	Description	Value (hex)
1	Object Identifier	06h
2	Label size	0Ch
3	Designation: ISO	2Bh

Byte No.	Description	Value (hex)
4	Designation: SMPTE	34h
5	Registry: Dictionaries	01h
6	Registry: Metadata Dictionaries	01h
7	Standard: Dictionary Number	01h
8	Version number	01h
9	Class: Identification and location	01h
10	Sub-class: Globally Unique Identifiers	01h
11	Type: UMID (Picture, Audio, Data, Group)	01, 02, 03, 04h
12	Type: Number creation method	XXh

Table 1: Specification of the UMID Universal Label

The hex values in Table 1 may be changed: the values given are examples. Also the bytes 1-12 may have designations other than those shown by way of example in the table. Referring to the Table 1, in the example shown byte 4 indicates that bytes 5-12 relate to a data format agreed by SMPTE. Byte 5 indicates that bytes 6 to 10 relate to "dictionary" data. Byte 6 indicates that such data is "metadata" defined by bytes 7 to 10. Byte 7 indicates the part of the dictionary containing metadata defined by bytes 9 and 10. Byte 10 indicates the version of the dictionary. Byte 9 indicates the class of data and Byte 10 indicates a particular item in the class.

In the present embodiment bytes 1 to 10 have fixed preassigned values. Byte 11 is variable. Thus referring to Figure 6B, and to Table 1 above, it will be noted that the bytes 1 to 10 of the label of the UMID are fixed. Therefore they may be replaced by a 1 byte 'Type' code T representing the bytes 1 to 10. The type code T is followed by a length code L. That is followed by 2 bytes, one of which is byte 11 of Table 1 and the other of which is byte 12 of Table 1, an instance number (3 bytes) and a material number (16 bytes). Optionally the material number may be followed by the signature metadata of the extended UMID and/or other metadata.

The UMID type (byte 11) has 4 separate values to identify each of 4 different data types as follows:

'01h' = UMID for Picture material

'02h' = UMID for Audio material

'03h' = UMID for Data material

'04h' = UMID for Group material (i.e. a combination of related essence).

The last (12th) byte of the 12 byte label identifies the methods by which the material and instance numbers are created. This byte is divided into top and bottom nibbles where the top nibble defines the method of Material number creation and the bottom nibble defines the method of Instance number creation.

Length

The Length is a 1-byte number with the value '13h' for basic UMIDs and '33h' for extended UMIDs.

Instance Number

The Instance number is a unique 3-byte number which is created by one of several means defined by the standard. It provides the link between a particular 'instance' of a clip and externally associated metadata. Without this instance number, all material could be linked to any instance of the material and its associated metadata.

The creation of a new clip requires the creation of a new Material number together with a zero Instance number. Therefore, a non-zero Instance number indicates that the associated clip is not the source material. An Instance number is primarily used to identify associated metadata related to any particular instance of a clip.

Material Number

The 16-byte Material number is a non-zero number created by one of several means identified in the standard. The number is dependent on a 6-byte registered port ID number, time and a random number generator.

Signature Metadata

Any component from the signature metadata may be null-filled where no meaningful value can be entered. Any null-filled component is wholly null-filled to clearly indicate a downstream decoder that the component is not valid.

The Time-Date Format

The date-time format is 8 bytes where the first 4 bytes are a UTC (Universal Time Code) based time component. The time is defined either by an AES3 32-bit audio sample clock or SMPTE 12M depending on the essence type.

The second 4 bytes define the date based on the Modified Julian Data (MJD) as defined in SMPTE 309M. This counts up to 999,999 days after midnight on the 17th November 1858 and allows dates to the year 4597.

The Spatial Co-ordinate Format

The spatial co-ordinate value consists of three components defined as follows:

•Altitude: 8 decimal numbers specifying up to 99,999,999 metres.

•Longitude: 8 decimal numbers specifying East/West 180.00000 degrees (5 decimal places active).

•Latitude: 8 decimal numbers specifying North/South 90.00000 degrees (5 decimal places active).

The Altitude value is expressed as a value in metres from the centre of the earth thus allowing altitudes below the sea level.

It should be noted that although spatial co-ordinates are static for most clips, this is not true for all cases. Material captured from a moving source such as a camera mounted on a vehicle may show changing spatial co-ordinate values.

Country Code

The Country code is an abbreviated 4-byte alpha-numeric string according to the set defined in ISO 3166. Countries which are not registered can obtain a registered alpha-numeric string from the SMPTE Registration Authority.

Organisation Code

The Organisation code is an abbreviated 4-byte alpha-numeric string registered with SMPTE. Organisation codes have meaning only in relation to their registered Country code so that Organisation codes can have the same value in different countries.

User Code

The User code is a 4-byte alpha-numeric string assigned locally by each organisation and is not globally registered. User codes are defined in relation to their registered Organisation and Country codes so that User codes may have the same value

in different organisations and countries.

Wavelets

Figures 7A and 7B illustrate wavelet processing and notation. Wavelets are well known and are described in for example "A Really Friendly Guide to Wavelets" by C Valens, 1999 (c.valens@mindless.com) and available at http://perso.wanadoo.fr/polyvalens/clemens/wavelets/wavelets.html.

Valens shows that the discrete wavelet transform can be implemented as an iterated filter bank as used in sub-band coding, with scaling of the image by a factor of 2 at each iteration.

Thus referring to Figure 7B, a spatial domain image is applied to a set of high pass HP and low pass LP filters. At level 1, the first stage of filtering, the image is filtered horizontally and vertically and, in each direction, scaled down by a factor of 2. In level 2, the low pass image from level 1 is filtered and scaled in the same way as in level 1. The filtering and scaling may be repeated in subsequent levels 3 onwards.

The result is shown schematically in Figure 7A. Figure 7A is a representation normal in the art. The horizontal axis indicates increasing horizontal frequencies and the vertical axis indicates increasing vertical frequencies. At level one the image is spatially filtered into four bands: the lower horizontal and vertical band, lH_1, lV_1; the upper horizontal band hH_1, lV_1; the upper vertical band lH_1, hV_1; and the upper horizontal and vertical band, hH_1, hV_1. At level 2, the lower horizontal and vertical band, lH_1, lV_1 is filtered and scaled into the lower horizontal and vertical band, lH_2, lV_2; the upper horizontal band hH_2, lV_2; the upper vertical band lH_2, hV_2; and the upper horizontal and vertical band, hH_2, hV_2. At level 3 (not shown in Figure 7A), the lower horizontal and vertical band, lH_2, lV_2 is further filtered and scaled.

In so far as the embodiments of the invention described above are implemented, at least in part, using software-controlled data processing apparatus, it will be appreciated that a computer program providing such software control and a storage medium by which such a computer program is stored are envisaged as aspects of the present invention.

Although particular embodiments have been described herein, it will be appreciated that the invention is not limited thereto and that many modifications and additions thereto may be made within the scope of the invention. For example, various

combinations of the features of the following dependent claims could be made with the features of the independent claims without departing from the scope of the present invention.